



U.S. NUCLEAR REGULATORY COMMISSION

STANDARD REVIEW PLAN

OFFICE OF NUCLEAR REACTOR REGULATION

15.6.5 RADIOLOGICAL CONSEQUENCES OF A DESIGN BASIS
LOSS-OF-COOLANT ACCIDENT:
Appendix B LEAKAGE FROM ENGINEERED SAFETY FEATURE COMPONENTS
OUTSIDE CONTAINMENT

REVIEW RESPONSIBILITIES

Primary - ~~Accident Evaluation Branch (AEB)~~ Emergency Preparedness and Radiation
Protection Branch (PERB)¹

Secondary - ~~Effluent Treatment Systems Branch (ETSB)~~ Plant Systems Branch (SPLB)²

I. AREAS OF REVIEW

Postulated radiological consequences from a loss-of-coolant accident (LOCA), assuming contributions from various release paths to the atmosphere, are treated in separate appendices to Standard Review Plan (SRP) Section 15.6.5, as follows:

Appendix A: Containment leakage, including the contribution from containment purge valves during closure.

Appendix B: Post-LOCA leakage from engineering safety feature (ESF) systems outside containment.

Appendix C: Post-LOCA hydrogen purge from containment. This appendix has been deleted.

Appendix D: Main steam isolation valve leakage (for boiling water reactor plants only).³

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USNRC STANDARD REVIEW PLAN

Standard review plans are prepared for the guidance of the Office of Nuclear Reactor Regulation staff responsible for the review of applications to construct and operate nuclear power plants. These documents are made available to the public as part of the Commission's policy to inform the nuclear industry and the general public of regulatory procedures and policies. Standard review plans are not substitutes for regulatory guides or the Commission's regulations and compliance with them is not required. The standard review plan sections are keyed to the Standard Format and Content of Safety Analysis Reports for Nuclear Power Plants. Not all sections of the Standard Format have a corresponding review plan.

Published standard review plans will be revised periodically, as appropriate, to accommodate comments and to reflect new information and experience.

Comments and suggestions for improvement will be considered and should be sent to the U.S. Nuclear Regulatory Commission, Office of Nuclear Reactor Regulation, Washington, D.C. 20555.

A potential source of fission product leakage following a ~~loss-of-coolant accident (LOCA)~~ is the leakage of water from ~~engineered safety features (ESF)~~⁴ equipment which is located outside the primary containment. Such leakage could occur during the recirculation phase for long-term core cooling and primary containment spray cooling. The fission products could then be released from the water into the atmosphere outside containment and, thus, result in offsite radiological consequences that contribute to the total dose from the hypothetical LOCA. To calculate the maximum leakage from recirculation loops following a hypothetical design basis LOCA, such sources as the following are considered: containment spray system, low-pressure safety injection system, and high-pressure safety injection system.

The primary review performed by PERB⁵ under SRP Section 15.6.5, Appendix B, includes the following:

- (1) The types of postulated leakage from ESF components, specifically including the leakage from valve stems and pump seals that can be expected during the operation of the ESF recirculation systems and the leakage from a postulated gross failure of an ESF passive component such as the failure of a pump seal.
- (2) The design and operational features that are provided to mitigate the potential for radiological consequences from this transport path such as a leakage collection system, atmosphere filtration system, and technical specifications for ESF component leakage.
- (3) The assumptions, model, and results of the dose calculations performed by the applicant for this fission product transport path. ~~The staff performs an independent analysis of the radiological consequences using conservative assumptions.~~⁶
- (4) An evaluation of the contribution of the radiological consequences of this transport path to the total radiological consequences from the hypothetical LOCA. ~~The reviewer should perform this aspect of the review in conjunction with the evaluation of the total radiological consequences under SRP Section 15.6.5, Appendix A.~~⁷

A secondary review is performed by ~~the Effluent Treatment Systems Branch (ETSB)~~SPLB⁸ and the results are used by ~~AEBPERB~~⁹ in the overall review of the accident analysis. ~~ETSB~~SPLB¹⁰ reviews the efficiency of the atmosphere filtration system to determine the iodine removal capability, and the results are transmitted to ~~AEBPERB~~¹¹ for use in the independent analysis.

II. ACCEPTANCE CRITERIA

The acceptance criteria are based on the requirements of 10 CFR ~~Part 100.11(a)~~¹² ~~(Ref. 2)~~¹³ as related to mitigating the radiological consequences of an accident. Specific criteria necessary to meet this requirement are as follows:

- (1) ESF systems that circulate water outside the containment are assumed to leak during their intended operation (e.g., valve stem leakage) and as a result of a failure of a passive component. Both types of leakage are included in the review. ESF atmosphere filtration

systems should be provided in those areas where such leakage is postulated to occur in order to mitigate the radiological consequences from the fission product release.

- (2) The postulated radiological consequences from the postulated leakage should be calculated using conservative assumptions. 50% of the core iodine inventory, based upon the maximum reactor power level, should be assumed to be mixed in the sump water being circulated through the containment external piping systems, in accordance with the values listed in Table 1 of Regulatory Guide 1.7¹⁴ (Ref. 1)¹⁵. The atmospheric dispersion factors (χ/Q values) as determined under SRP Section 2.3.4 should be used in the analysis.
- (3) The postulated¹⁶ radiological consequences from ESF component leakage, as calculated by the staff, should be combined, under SRP Section 15.6.5, Appendix A, with the consequences from other fission product release paths to determine the total calculated radiological consequences from the hypothetical LOCA. The acceptability of the site, with respect to the total radiological consequences, is determined by the adequacy of the exclusion area and low population zone outer boundary distances in conjunction with the operation of dose-mitigating ESF systems. For operating license (OL),¹⁷ combined license (COL), or early site permit applications,¹⁸ the total doses should be within the exposure guidelines of 10 CFR Part 100, §100.11(a)¹⁹ (Ref. 2)²⁰ and, for For²¹ a construction permit application, the total doses should be within the guideline value of Regulatory Guides 1.3 (Ref. 3)²² and 1.4 (Ref. 4)²³, as appropriate. This acceptability is determined under SRP Section 15.6.5, Appendix A.

Technical Rationale²⁴

The technical rationale for application of these acceptance criteria is discussed in the following paragraphs:²⁵

Compliance with 10 CFR 100.11(a) requires that radiation dose calculations be performed at the exclusion area and low population zone. These calculations shall assume a given fission product release from the core, an expected leak rate from the containment, and meteorological conditions pertinent to the site.

The identification of an exclusion area, a low population zone, and a population center distance is an integral part of the siting criteria for new nuclear power plants. Radiation dose guidelines of 0.25 Sv (25 rem) to the whole body or 3 Sv (300 rem) to the thyroid from iodine exposure are associated with the exclusion area (2-hour exposure) and the low population zone (30-day exposure). Expected offsite radiation doses are calculated to verify that the proposed plant design meets established guidelines using a radioactive source term that is based on reactor parameters immediately preceding the LOCA, the leakage rate of the containment, and site-specific atmospheric dispersion characteristics.

Meeting the requirements of 10 CFR 100.11(a) provides assurance that offsite radiation doses from postulated accidents will not result in undue risk to the health and safety of the public.²⁶

III. REVIEW PROCEDURES

The reviewer selects and emphasizes aspects covered by this appendix as appropriate for a particular case. The judgment of which areas need to be given attention and emphasis in the review is based on a determination if the material presented is similar to that recently reviewed on other plants and whether items of special safety significance are involved. The reviewer then performs an independent analysis of the radiological consequences of recirculation leakage using conservative assumptions.²⁷

The applicant's recirculation leakage assumptions and calculation are compared with previously licensed plants for accuracy and completeness. It is assumed that 50% of the core iodine inventory, based upon the maximum reactor power level, is mixed in the sump water being circulated through the external piping systems per Regulatory Guide 1.7(Ref. 1)²⁸. Credit may be allowed for radioactive decay of the iodine during the time period from the occurrence of the LOCA up to the beginning of recirculation when the sump water is circulated outside the containment.

The leakage for calculating the radiological consequences should be the maximum operational leakage and should be taken as two times the sum of the simultaneous leakage from all components in the recirculation systems above which the technical specifications would require declaring such systems to be out of service. The leakage is assumed to occur throughout the accident, starting at the earliest time that the recirculation mode is initiated.

For a plant that does not provide an ESF atmosphere filtration system, the dose assessment should also include the leakage from a gross failure of a passive component. This leakage should conservatively be assumed to be 3.2 liters per second (50 gallons per minute),²⁹ starting at 24 hours after the accident and lasting for 30 minutes. For a plant that does provide an ESF atmosphere filtration system in the areas of potential leakage from a gross failure of passive components, such dose assessment need not be performed.

The applicant's information on the time-dependent temperature of the sump water circulating outside containment after the LOCA is evaluated. For a water temperature above 100°C (212°F),³⁰ the fraction of the leakage that flashes to steam is determined assuming a constant enthalpy process. If the flash fraction is greater than 10%, then this fraction is taken as the fraction of iodine in the leakage that becomes airborne. If the calculated flash fraction is less than 10% or if the water is less than 100°C (212°F),³¹ then 10% of the iodine in the leakage is assumed to become airborne unless a smaller amount is justified based on actual sump pH history and ventilation rates.

The airborne iodine is assumed to be released immediately to the environment. The atmospheric dispersion is based upon the ground level χ/Q values determined under SRP Section 2.3.4. Atmosphere filtration system filters are evaluated by the ETSB SPLB³² with respect to the guidelines of Regulatory Guide 1.52(Ref. 5)³³ for appropriate credit to be given for iodine removal by the filters. The doses at the nearest exclusion area boundary and low population zone LPZ³⁴ outer boundary are calculated using appropriate assumptions and methods as described in Appendix A to SRP Section 15.6.5, Appendix A³⁵.

The reviewer evaluates the contribution of the radiological consequences of this transport path to the total radiological consequences from the hypothetical LOCA.³⁶ The doses calculated by the staff are reported in the dose table of the section, "Radiological Consequences of a LOCA," which is prepared in accordance with SRP Section 15.6.5, Appendix A.

For standard design certification reviews under 10 CFR Part 52, the procedures above should be followed, as modified by the procedures in SRP Section 14.3 (proposed), to verify that the design set forth in the standard safety analysis report, including inspections, tests, analysis, and acceptance criteria (ITAAC), site interface requirements and combined license action items, meet the acceptance criteria given in subsection II. SRP Section 14.3 (proposed) contains procedures for the review of certified design material (CDM) for the standard design, including the site parameters, interface criteria, and ITAAC.³⁷

IV. EVALUATION FINDINGS

The reviewer verifies that the applicant has provided sufficient information for the staff to perform an independent calculation of the thyroid and whole-body doses due to leakage from ESF components outside containment as the fission product release path. The calculated doses are reported in the safety evaluation report (SER) in Table 15.____ under SER Section 15.____, "LOCA Radiological Consequences," in accordance with SRP Section 15.6.5, Appendix A. The same SER section will also include the staff's findings with respect to the total calculated doses from all release paths and with respect to the acceptability of the exclusion area and low population zone boundaries on the basis of the total calculated doses in accordance with the guideline values of 10 CFR ~~Part~~ 100.11(a).³⁸

Following the summary section on the total radiological consequences, separate SER subsections will present the staff's evaluation and finding for each specific fission product release path. For the ESF component leakage path reviewed under this SRP Section 15.6.5, Appendix B, the staff's independent review and calculations should support a conclusion of the following type:

The radiological consequences resulting from leakage from ESF components located outside containment following the hypothetical design basis loss-of-coolant accident were evaluated. The staff reviewed the applicant's analysis and has performed independent calculations. These calculations are based on conservative assumptions. The fission product source term in the leakage meets the guidelines of Regulatory Guide 1.7. The atmospheric dispersion characteristics (χ/Q values) used in the calculations are those stated in Section 2.3.4 of this report.

The results of the calculation are reported in Table 15.____. The contribution of the ESF leakage doses to the total calculated radiological consequences of the LOCA is evaluated in Section 15.

For design certification reviews, the findings will also summarize, to the extent that the review is not discussed in other safety evaluation report sections, the staff's evaluation of inspections, tests, analyses, and acceptance criteria (ITAAC), including design acceptance criteria (DAC), site interface requirements, and combined license action items that are relevant to this SRP section.³⁹

V. IMPLEMENTATION

The following provides guidance to applicants and licensees regarding the staff's plans for using this SRP section.

This SRP section will be used by the staff when performing safety evaluations of license applications submitted by applicants pursuant to 10 CFR 50 or 10 CFR 52.⁴⁰ Except in those cases in which the applicant proposes an acceptable alternative method for complying with specified portions of the Commission's regulations, the method described herein will be used by the staff in its evaluation of conformance with Commission regulations.

The provisions of this SRP section apply to reviews of applications docketed six months or more after the date of issuance of this SRP section.⁴¹

Implementation schedules for conformance to parts of the method discussed herein are contained in the referenced regulatory guides.

VI. REFERENCES

1. Regulatory Guide 1.7, "Control of Combustible Gas Concentrations in Containment Following a Loss-of-Coolant Accident."
2. 10 CFR Part 100,⁴² 100.11, "Determination of Exclusion Area Low Population Zone and Population Center Distance."
3. Regulatory Guide 1.3, "Assumptions Used for Evaluating the Potential Radiological Consequences of a Loss-of-Coolant Accident for Boiling Water Reactors."
4. Regulatory Guide 1.4, "Assumptions Used for Evaluating the Potential Radiological Consequences of a Loss-of-Coolant Accident for Pressurized Water Reactors."
5. Regulatory Guide 1.52, "Design, Testing, and Maintenance Criteria for Atmosphere Cleanup System Air Filtration and Adsorption Units of Light-Water-Cooled Nuclear Power Plants."

SRP Draft Section 15.6.5
Attachment A - Proposed Changes in Order of Occurrence

Item numbers in the following table correspond to superscript numbers in the redline/strikeout copy of the draft SRP section.

Item	Source	Description
1.	Current PRB name and abbreviation	Changed PRB to Emergency Preparedness and Radiation Protection Branch (PERB).
2.	Current SRB name and abbreviation	Changed SRB to Plant Systems Branch (SPLB).
3.	Editorial	Added paragraph on contents of the appendices to SRP Section 15.6.5.
4.	Editorial	Deleted repeated definitions for "LOCA" and "ESF."
5.	Editorial	Identified PERB as the PRB.
6.	Editorial	Sentence describing staff review procedures belongs in REVIEW PROCEDURES.
7.	Editorial	Sentence describing staff review procedures belongs in REVIEW PROCEDURES.
8.	Current SRB abbreviation	Changed SRB to SPLB. The full name of the branch was identified under REVIEW RESPONSIBILITIES.
9.	Current PRB abbreviation	Changed PRB to PERB.
10.	Current SRB abbreviation	Changed SRB to SPLB.
11.	Current PRB abbreviation	Changed PRB to PERB.
12.	Editorial	Corrected citation format for 10 CFR 100.11(a).
13.	SRP-UDP format item	Deleted callout for Ref. 2.
14.	Integrated Impact 633	Consideration should be given to determining whether the RG 1.7 assumption of 50% of the core inventory of iodine mixed in the sump water is still appropriate.
15.	Editorial	Removed reference 1 to be consistent with other section RG citations.
16.	Editorial	Added "postulated" for clarity and consistency.
17.	Editorial	Provided "OL" as abbreviation for "operating license."
18.	SRP-UDP format item	Added COL and early site review applications per 10 CFR Part 52.
19.	Editorial	Corrected citation format for 10 CFR 100.11(a).
20.	SRP-UDP format item	Deleted callout for Ref. 2.
21.	Editorial	Simplified and clarified a complex sentence by creating two separate sentences.
22.	SRP-UDP format item	Deleted callout for Ref. 3.

SRP Draft Section 15.6.5
Attachment A - Proposed Changes in Order of Occurrence

Item	Source	Description
23.	SRP-UDP format item	Deleted callout for Ref. 4.
24.	SRP-UDP format item	Added "Technical Rationale" to ACCEPTANCE CRITERIA to describe the basis for referencing 10 CFR 100.11(a).
25.	SRP-UDP format item	Added lead-in sentence for "Technical Rationale."
26.	SRP-UDP format item	Added technical rational for 10 CFR 100.11(a).
27.	Editorial	Added requirement to prepare an independent evaluation of the radiological consequences of recirculation leakage as specified in AREAS OF REVIEW, subparagraph (3).
28.	SRP-UDP format item	Replaced callout of Ref. 1 with "per Regulatory Guide 1.7.
29.	SRP-UDP format item	Added SI units.
30.	SRP-UDP format item	Added SI units.
31.	SRP-UDP format item	Added SI units.
32.	Current SRB abbreviation	Changed SRB to SPLB.
33.	SRP-UDP format item	Deleted callout for Ref. 5.
34.	Editorial	Defined "LPZ" as "low population zone."
35.	Editorial	Revised designation to SRP Section 15.6.5, Appendix A.
36.	Editorial	Added requirement to evaluate total radiological consequences of a LOCA as specified in AREAS OF REVIEW, subparagraph (4).
37.	SRP-UDP Guidance, Implementation of 10 CFR 52	Added standard paragraph to address application of Review Procedures in design certification reviews.
38.	Editorial	Corrected citation format for 10 CFR 100.11(a).
39.	SRP-UDP Format Item, Implement 10 CFR 52 Related Changes	To address design certification reviews a new paragraph was added to the end of the Evaluation Findings. This paragraph addresses design certification specific items including ITAAC, DAC, site interface requirements, and combined license action items.
40.	SRP-UDP Guidance, Implementation of 10 CFR 52	Added standard sentence to address application of the SRP section to reviews of applications filed under 10 CFR Part 52, as well as Part 50.
41.	SRP-UDP Guidance	Added standard paragraph to indicate applicability of this section to reviews of future applications.
42.	Editorial	Corrected citation format for 10 CFR 100.11.

SRP Draft Section 15.6.5

Attachment A - Proposed Changes in Order of Occurrence

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SRP Draft Section 15.6.5
Attachment B - Cross Reference of Integrated Impacts

Integrated Impact No.	Issue	SRP Subsections Affected
633	Consideration should be given to determining whether the RG 1.7 assumption of 50% of the core inventory of iodine mixed in the sump water is still appropriate.	No changes to SRP 15.6.5B.